



Influence of Selected Soil Properties on Early Growth of *Tectona Grandis* Seedlings in Benue State, Nigeria

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Abstract— This study evaluated the effects of soil properties from five locations in Benue State, Nigeria, on the early growth of *Tectona grandis* (teak) seedlings. Bulk composite soil samples (0–30 cm depth) were collected 500 m from teak plantations in Amilogodo (Oju), Aghan (Makurdi), Mbagba (Ushongo), Ihugh (Vandekiya), and Ijami (Ohimini). Soils were analyzed for physico-chemical properties, and treated seeds were germinated then transplanted into polypots for six months. Growth parameters included seedling height (cm), leaf number, leaf area index (LAI; cm²), and dry biomass (g). Data were analyzed using one-way ANOVA and LSD tests ($p < 0.05$). Soil E (Ohimini; pH 6.10, CEC 7.52 cmol kg⁻¹, organic C 2.28%, total N 0.09%, available P 6.75 mg kg⁻¹) yielded superior performance (height 11.74 cm, LAI 11.30 cm², dry biomass 4.44 g). Well drained loamy soil with high nitrogen content, high CEC, organic matter content and available phosphorus is most suitable for the establishment of *Tectona grandis* plantation. Therefore, soils with characteristics similar to that of sample E (Ohimini) is recommended for the establishment of Teak (*Tectona grandis*) plantation Benue State.



Keywords— Growth performance, Teak, Seedling, Soil samples and Leaf Area Index

I. INTRODUCTION

Naturally, plant species perform according to the productive capacity of the soil under good management, this explains the intrinsic relationship between plant growth and soil fertility. Where nutrients necessary for plant to perform optimally are not available or inadequate, the need to supplement the soil nutrient is a key factor in agriculture, forestry, horticulture (Lal, 2015). Teak (*Tectona grandis*): Family Verbenaceae is a plantation species that was probably introduced to Nigeria from Burma. The first recorded planting of teak in Nigeria was made in 1889, when it was introduced to the Botanical Gardens at Ebute-metta Unwin (1920), and the oldest teak plantation in Nigeria was raised from Burma teak seeds and established at Olekemeji in Abeokuta province. Teak (*Tectona grandis*) is one of the most important hardwoods of the world trade. In Nigeria, teak is used as a subsidiary species to most indigenous species in plantation centers. It

is a favoured species in Nigeria because it supports agroforestry and commercial plantations, also, its fast growth, site tolerance, and good stem form, straight and durable boles which can produce valuable immediate and final yield of wood makes it a highly value wood crop (Akor, 1981). Teak is one of the exotics, which its main uses rely on its aesthetic and decorative quality and its excellent working properties.

Recent studies highlight teak's sensitivity to soil pH (5.5–7.5), organic matter, N, P, and CEC, with optimal growth in loamy, moderately acidic soils (Behera *et al.*, 2019; Onyekwelu *et al.*, 2021). In Nigeria, low N and P often limit seedling vigor (Adebayo *et al.*, 2023; Eze *et al.*, 2024). This study assesses soil properties from Benue State teak sites on seedling performance, building on foundational work (Harpstead, 1973) with contemporary data to guide plantation establishment.

II. MATERIALS AND METHODS

2.1 Description of the Study Area

The experiment was conducted at the Teaching and the Research Farm of the Joseph Sarwuan Tarka University Makurdi, (JOSTUM) in Benue state, Nigeria between the months of December 2024 and May 2025. JOSTUM is located at latitude 7.41°N and longitude 8.35°E at an elevation of about 97 meters above the sea level. This location falls within the Southern Guinea Savanna Agro-ecological zone of Nigeria.

2.2 Experimental Design and soil sampling

The experimental design was a completely randomized design (CRD) with five treatments (soil samples A–E) and five replicates (n=25). The purpose for this type of design is to subject all samples to equal distribution of treatment regimes. Composite and undisturbed soil samples in replicates were obtained from the five locations. The samples were collected randomly at about 500 m from the edges of teak plantations at the depth of 0-30 cm. This was to minimize the influence of litter deposit on the soil around the perimeter of the plantations. The various bulk soil samples were then taken to the advance soil testing Laboratory, Joseph Sarwaun Tarka University, Makurdi, for analysis.

2.3 Soil Analysis

The soil samples were analyzed for selected physical and chemical properties. Physical properties such as Particle Size Distribution (PSD) were determined by hydrometer method, Bouyoucos (1951), while the soil textures were determined by the USDA textural triangle. Soil Bulk Density (BD) was determined using the core method. The chemical properties of the soil such as, the soil pH in KCl (1:1), Organic Carbon content of the soil were determined by electrometric method and wet oxidation method by Walkley and Black (1934) respectively. Macro-Kjeldahl digestion method was used in determining the total Nitrogen. Cation Exchange Capacity (CEC) was determined by neutral, 1N Ammonium acetate method while Bray-1 method of molybdate blue colorimetry was used to determine the extractable phosphorus.

2.4 Seed Source and Pre-treatments

Teak seeds were sourced locally from stands in the University Staff quarters of JOSTUM. The seeds were subjected to pre-treatments, where, 80 fruits soaked in running water (2 or 3 days, with alternate drying for

cracking). Seeds germinated in boxes for 2 weeks, then transplanted to polypots and watered uniformly for the period of the experiment.

Seedling height (cm), leaf number, LAI (Watson, 1947), and dry biomass (g; oven-dried at 70°C) were measured at 6 months. Analysis of variance test (ANOVA) and least significant difference (LSD) ($P < 0.05$) were performed in R (v4.4).

III. RESULTS

3.1 Soil Analysis

The result of the particle size distribution presented in Table 1 indicated different textural composition of the soils. While sample E is a loamy soil, sample A belongs to the textural class of loamysand, soil samples B, C, and D are sandyloam. Also in Table 1, bulk density (BD) of the samples ranged from 1.51gcm⁻³ at A to 1.64gcm⁻³ at E.

The result in Table 1 shows that soil samples A, B, C, D and E have pH values that range from 6.10 to 6.55 (Average 6.36) which is slightly acidic. These are typical characteristics of savanna soils. Harpstead (1973) reported that Guinea Savanna soils are less leached and are of moderate to near neutral acid condition. The CEC varied from 5.35 cmol/kg. to 7.52 Cmol/kg. The organic carbon varied from 1.91% to 2.29% (Average 2.26%) while the total nitrogen and phosphorus varied from 0.03% to 0.09% averaging 0.06% and 5.70 mg kg⁻¹ and 6.04 mg kg⁻¹ respectively. From the result, a soil of pH 6.3, CEC 6.48 mol/kg, organic carbon 1.91% and total nitrogen and phosphorus 0.06% and 6.04 mg/kg.

3.2 Measures of performance:

Evaluation of early growth performance of Teak are presented in Table 2. Treatment E recorded the highest mean height (11.74cm) followed by A (10.5cm) with treatment C coming last (7.99cm). Though difference in height measurements were observed in the different soil samples (treatments). ANOVA, however, showed no significant difference in height among the treatments (Table 3). Number of leaves per plant showed a similar trend with plant height, the highest leave numbers were recorded in treatment E (13.60) while the least was recorded in treatment C (12.00) Table 2.

Table 1: Physico-Chemical Properties of the Soil samples

Sampled sites	Samples	Bulk Density (gcm ⁻³)	Sand (%)	Silt (%)	Clay (%)	Textural Class	pH	CEC CMol/Kg	Organic Carbon (%)	Total Nitrogen (%)	Avail.P (mg/kg)
Oju (Amilogodo)	A	1.51	85	12	3	Loamysand	6.18	5.50	2.29	0.09	6.40
Makurdi (Aghan)	B	1.49	78	15	7	Sandyloam	6.62	5.91	1.91	0.03	5.70
Ushongo (Mbagba)	C	1.54	76	13	11	Sandyloam	6.55	6.45	2.51	0.04	6.20
Vandekyi a (Ihugh)	D	1.56	78	14	8	Sandyloam	6.50	5.10	2.33	0.06	6.10
Ohimini (Ijani)	E	1.64	65	16	19	Loam	6.10	7.52	2.28	0.09	6.75

Table 2: Effect of soil properties on early growth parameters of *Teak*

Parameters	A	B	C	D	E	LSD (p>0.05)
Height (cm)	10.5	9.28	7.99	9.40	11.74	2.87
Leaf number	12.8	12.4	12.0	12.4	13.6	2.93
LAI (cm ²)	9.8	7.3	7.5	8.6	11.3	2.55
Dry biomass (g)	3.84	1.94	2.07	2.81	4.44	2.58

Table 2 further showed average leaf area index for each treatment at the end of the experiment. Treatment E recorded the highest mean leaf area index (11.30cm) followed by A (9.80cm) with treatment B coming last (7.30). ANOVA Table 3 showed significant difference between the treatments. A follow-up test was carried out using LSD and significant differences were observed between treatment E and B, and C as shown in Table 4.

The average biomass for each treatment at the end of the experiment are also presented in Table 2. Treatment E

recorded the highest mean dry weight (4.44 g), followed by A (3.84g), with the treatment B coming last (1.94 g). The variation in the dry matter was tested with ANOVA, which showed significant difference between the treatments (Table 3). A follow up test was carried out using least significant difference (LSD >0.05) and significant differences were observed between treatments E and B, and C, E and D, A and B, A and C and finally between A and D as shown in Table 4.

Table 3: The ANOVA for plant height, number of leaves, leaf area index and dry matter biomass

SV	df	Ss	Ms	F.cal	F. Tab 5%	1%
Plant height						
Treatment	4	39.68	9.92	2.49	2.87	4.43
Error	20	79.64	3.98			
Total	24	119.32				
Leaf area index						
Treatment	4	55.90	13.975	5.12	2.87	4.43
Error	20	54.60	2.73			
Total	24	110.50				
Dry matter biomass						
Treatment	4	23.90	5.975	5.10	2.87	4.43
Error	20	23.41	1.1705			
Total	24	47.31				

Table 4: Follow up test LSD ($t = 0.05, df = 20$) for leaf area index and dry matter biomass

	*	E	A	D	C	B
Leaf area index (3.352)						
B	7.30	11.30	9.80	8.64	7.54	7.30
C	7.50	4.00*	2.50	1.30	-	
D	8.60	3.80*	2.30	-		
A	9.80	2.70	-			
E	11.30	-				
Dry matter biomass (0.984)						
B	1.94	4.44	3.84	2.81	2.07	1.94
C	2.07	2.50*	1.90*	0.87	-	-
D	2.81	2.37*	1.77*	-		
A	3.84	1.63*	-			
E	4.44	-				

*Significantly difference

3.3 Effect of soil properties on the early growth performance of Teak

The data in Table 5 summarizes the relationship between soil properties and early growth performance of Teak (*Tectona grandis*) across five soil treatments (A–E). Teak seedlings in Treatment E (Ohimini) grew tallest, suggesting more favorable soil conditions, possibly linked

to higher nutrient availability or improved soil structure. A higher leaf count here, also indicates better vegetative growth and photosynthetic capacity in Treatment E. Leaf area correlates with nutrient uptake efficiency; Treatment E equally promotes greater canopy development. The biomass accumulation trend aligns with height and leaf index, confirming more robust growth in Treatment E.

Treatment E consistently produced superior growth outcomes, while B and C lagged (Table 5), implying differences in soil fertility, nutrient balance, and possibly moisture-holding capacity. The pH range of 6.10 – 6.52 across all the treatment (Table 5) are indicative of slightly acidic to neutral state of the soils, this are optimal for teak growth. Cation exchange capacity CEC were highest (7.52 cmol kg⁻¹) in treatment E and lowest in D (5.10 cmol kg⁻¹) (Table 5). High CEC in E is an indication of greater nutrient retention, supporting better growth. Organic

carbon (%) was relatively stable (Table 5). Although B had the highest OC (2.91%), its poor growth suggests that OC alone wasn't the dominant factor possibly due to low nitrogen or imbalance in other nutrients. Total nitrogen (%) was highest in A and E (0.09%), Table 5. Nitrogen is essential for foliage and shoot growth, which aligns with taller plants and more leaves in these treatments.

Available phosphorus (mg kg⁻¹) was highest in E (6.75). Adequate P enhances root formation and early vigor directly explaining higher dry matter and height.

Table 5. Summary of effect of soil properties on the early growth performance of Teak

Parameters	Treatments				
	A	B	C	D	E
Average height (cm)	10.5	9.28	7.99	9.40	11.74
Average no of leaves	12.80	12.40	12.00	12.40	13.60
Leaf index(g)	9.8	7.30	7.50	8.60	11.30
Dry matter(g)	3.84	1.94	2.07	2.81	4.44
pH	6.18	6.62	6.55	6.50	6.10
CEC cmol/kg	5.50	5.90	6.45	5.10	7.52
Organic carbon (%)	2.29	2.91	2.51	1.91	2.28
Total nitrogen (%)	0.09	0.03	0.03	0.06	0.09
Available phosphorus(p) (mg kg ⁻¹)	6.40	5.70	6.20	6.10	6.75

IV. DISCUSSION

Treatment E (the soils from Ohimini) offers the most fertile combination moderate pH (6.10), highest CEC (7.52), balanced OC (2.28%), and high N and P availability. These factors together enhance nutrient absorption, root proliferation, and photosynthetic efficiency, leading to superior height, leaf area, and biomass. By contrast, Treatments B and C, though slightly higher in pH and OC, show reduced nitrogen and phosphorus, resulting in stunted growth. That aligns with the nutrient limitation patterns noted by Abankwa et al. (2017), where teak plantations with nutrient deficiencies (especially N and P) demonstrated significantly reduced growth.

Soil E's superior performance correlates with higher CEC, N, P, and loam texture, facilitating nutrient retention and root development consistent with teak's preferences (Behera et al., 2019). Low N in B/C mirrors poor biomass in Nigerian savanna soils (Adebayo et al., 2023). Leaf area index (LAI) and biomass sensitivity underscores their utility for early vigor assessment (Onyekwelu et al., 2021; Eze et al., 2024), linking to photosynthesis and biomass allocation. Unlike height, these reflect fertility gradients, aligning with Williams & Richardson (1987) that nitrogen

is the most important in tree nutrition and it accounts for about 1-3% dry weight of tree composition. And that high acidic condition of the soil inhibits activities of many common bacteria, algae and actinomycetes. Also phosphorus is vital to life and portion of all green plants. High organic carbon indicates high nutrient deposition.

Although, significant differences were not noted in the parameters like leaf count and height, dry matter and Leaf Area Index (LAI) showed significant differences. It is important to monitor the distribution and changes of LAI so that growth and vigour of vegetation on planet can be assessed. Important parameters for climate models and land-surface processes are obtained from LAI. Various processes such as photosynthesis, respiration, transpiration and rain interception which controls the links between biosphere and atmosphere are determined in the variables representing the amount of leaf material in ecosystems. The characteristics of all the parameters observed were more outstanding in sample E followed by A, this is an indication that, the nutrients available especially nitrogen supported the growth of the trees. High dry weights of treatment E and A could be attributed to high nitrogen composition, phosphorus, organic carbon and all other requisite for the growth of tree.

V. CONCLUSION AND RECOMMENDATION

A study was undertaken to evaluate the influence of soil nutrients on the early growth performance of Teak (*Tectona grandis*) in Benue state. The physical properties of the soil such as the Bulk density (BD), Particle size distributions (PSD) and the chemical properties such as the soil pH, total nitrogen, phosphorus, organic carbon and Cation Exchange Capacity (CEC) were analyzed. Also, data on plant parameters such the plant height, number of leave per plant, dry matter as well as leave area index were assessed to check their response to the soil nutrient elements studied.

Early growth performance of *Tectona grandis* is strongly influenced by nitrogen level, CEC, and available phosphorus. Treatments with higher nutrient-holding capacity and balanced soil chemistry (especially E) produced superior results. The study showed that the soil sample E from Ohimini, a deep and well drained loamy soil gave the highest response in terms of growth performance with respect to the soil nutrient elements studied.

Based on the findings of this investigation, the following recommendations have been advanced with respect to establishment of teak plantation.

1. Well drained loamy soil with high nitrogen content, high CEC, organic matter content and available phosphorus is most suitable for the establishment of *Tectona grandis* plantation. Therefore, soils with characteristics similar to that of sample E (Ohimini) is recommended for the establishment of Teak (*Tectona grandis*) plantation Benue State.
2. It is also recommended that similar research be carried out for a longer duration to cover the growth period beyond nursery to maturity, so as to assess its response to different soil conditions.
3. Furthermore, government should encourage the establishment of teak plantation because of its economic importance through subsidies on inputs so as to encourage prospective farmers to venture in the production.

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